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मानक

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IS 15635-5 (2006): Geometrical Products specifications (GPS) - Acceptance and reverification tests for coordinate measuring machines (CMM) : Part 5 CMMs using multiple - stylus probing systems [PGD 25: Engineering Metrology]



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भारतीय मानक

ज्यामितीय उत्पाद विशिष्टि (जी.पी.एस.) — संयोजी मापन
मशीनों (सी.एम.एम.) की स्वीकार्यता और पुर्नजाँच परीक्षण

भाग 5 बहुल-स्टाईल्स प्रोबिंग पद्धतियाँ

Indian Standard

**GEOMETRICAL PRODUCT SPECIFICATIONS
(GPS) — ACCEPTANCE AND REVERIFICATION
TESTS FOR COORDINATE MEASURING
MACHINES (CMM)**

PART 5 CMMs USING MULTIPLE-STYLUS PROBING SYSTEMS

ICS 17.040.30

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

NATIONAL FOREWORD

This Indian Standard (Part 5) which is identical with ISO 10360-5 : 2000 'Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 5 : CMMs using multiple-stylus probing systems' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Engineering Metrology Sectional Committee and approval of the Medical Instruments, General and Production Engineering Division Council.

Coordinate measuring machines (CMMs) are most modern method of dimensional inspection. With the advent of numerically controlled machine tools, demand grew for a means to support this equipment with faster first piece inspection and in many cases 100 percent inspection. To fill this gap CMMs were developed by modifying precision layout machines.

The acceptance and reverification tests described in this part of standard are applicable to CMMs that use more than one stylus, or stylus orientation, when measuring a workpiece.

Experience has shown that errors calculated using this part of ISO 10360 are significant and, at times, the dominant errors in the CMM. Owing to the virtually infinite variety of modern CMM probing-system configurations, the tests specified in this part have been limited to providing a testing format only. The tests are intended to provide information on the ability of a CMM to measure a feature, or features, using multiple styli, probes or articulated-probe positions.

The situations to which they are applicable include:

- multiple styli connected to the CMM probe (for example, a star),
- installations using an articulating probing system (motorized or manual) that can be prequalified,
- installations using a repeatable probe-changing system,
- installations using a repeatable stylus-changing system, and
- multiple-probe installations.

It is believed that the procedures given in this part will be helpful in minimizing probing system uncertainty components for specific measurement tasks, and that the user will be able to reduce errors by removing contributing elements such as long extensions and styli, then retesting the new configuration set.

The tests in this part of ISO 10360 are sensitive to many errors attributable to both the CMM and the probing system and are to be performed in addition to the size-measuring test given in ISO 10360-2 (conducted using only one stylus), and in addition to, or instead of, the test of the probing system specified.

The text of this ISO Standard has been proposed to be approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
- b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their places are listed below along with their degree of equivalence for the editions indicated:

Indian Standard

**GEOMETRICAL PRODUCT SPECIFICATIONS
(GPS) — ACCEPTANCE AND REVERIFICATION
TESTS FOR COORDINATE MEASURING
MACHINES (CMM)**

PART 5 CMMs USING MULTIPLE-STYLUS PROBING SYSTEMS

1 Scope

This part of ISO 10360 specifies acceptance and periodic reverification tests of the performance of CMMs having multiple-stylus probing systems, including systems with fixed multiple-styli attached to a single probe (e.g. "star" stylus), multiple-probing systems such as those with a stylus for each of their probes, and systems with articulating probing.

The acceptance test and reverification test specified in this part of ISO 10360 are applicable only to the following:

- CMMs using any type of contact-probing system;
- stylus system configurations able to be prequalified (i.e. where the repeatability of the system operation is sufficient so that a stylus qualification is not required for each use);

NOTE In the case of prequalified configurations, a similar test could be devised for non-repeatable changes of stylus system configurations.

- spherical, hemispherical and disk-shaped styli.

These tests are not applicable to non-contact probing systems, which require special testing procedures outside the scope of this part of ISO 10360.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10360. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10360 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 10360-1:2000, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1: Vocabulary*.

ISO 14253-1:1998, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformance or non-conformance with specifications*.

International Vocabulary of Basic and General Terms in Metrology (VIM). BIPM, IEC, IFCC, IUPAC, IUPAP, OIML, 2nd edition, 1993.

3 Terms and definitions

For the purposes of this part of ISO 10360, the terms and definitions given in ISO 10360-1, ISO 14253-1 and VIM apply.

4 Requirements for metrological characteristics

4.1 Errors of indication

The fixed multiple-stylus probing system errors and the articulating probing system errors, MF , MS , ML , and AF , AS , AL , respectively, shall not exceed the corresponding maximum permissible errors (MPE_{MF} , MPE_{MS} , MPE_{ML} , and MPE_{AF} , MPE_{AS} , MPE_{AL}), as stated by:

- the manufacturer, in the case of acceptance tests;
- the user, in the case of reverification tests.

The errors and their corresponding maximum permissible errors are expressed in micrometres.

NOTE Multiple-stylus probing system errors are broadly categorized into form-related (MF , AF), size-related (MS , AS) and location-related (ML , AL) errors. Different combinations of these will be important for the uncertainty of the different measurement tasks.

4.2 Environmental conditions

The limits to be respected for permissible environmental conditions that influence the measurements, such as temperature, air humidity and vibration at the site of installation, shall be specified by

- the manufacturer, in the case of acceptance tests, or
- the user, in the case of reverification tests.

In either case, the user may choose the conditions from within the specified limits.

4.3 Styli

The styli used in the tests specified in clause 5 shall be those approved for use with the CMM, i.e. made of the same material, of the same stylus-shaft diameter and nominal length, and having the same stylus-tip quality. However, it is recognized that the exact stylus lengths used for test procedures might not be available, and therefore a stylus-length variation of 6 mm or 10 % of the nominal length, whichever is the greater, may be used.

4.4 Operating conditions

For the tests specified in clause 5, the CMM shall be operated using the procedures given in the manufacturer's operating manual. Specific areas of the manufacturer's manual to be adhered to include

- a) machine start up/warm up cycles,
- b) stylus system configuration and assembly,
- c) cleaning procedures for stylus tip and reference sphere, and
- d) probing system qualification.

All stylus tips and the reference sphere should be cleaned before the probing-system qualification to eliminate residual film which might affect the measurements or test results.

Ensuring approximate thermal equilibrium of the probing system before and during the probing system qualification is critical to the test.

5 Acceptance tests and reverification tests

5.1 Fixed multiple-stylus probing system

5.1.1 Principle

The principle of this test procedure is to measure the form, size and location of a test sphere using five different fixed styli. Each stylus probes 25 points on the test sphere, for a total of 125 points for all five styli.

If a stylus or probe changing system is supplied with the CMM, five changes shall be performed, one before each stylus is used. For each group of 25 points taken with a single stylus, associate a least-squares sphere fit, for a total of five sphere fits.

The ranges of the centre coordinates (X, Y, and Z) of all five spheres are calculated. The largest of these three ranges yields the location error *ML*. In addition, a least-squares sphere fit using all 125 points is examined for the form and size errors of indication. This analysis yields the size error *MS* and form error *MF*.

Since the results of these tests are highly dependent on the stylus system, a series of stylus lengths is considered; only those lengths the CMM manufacturer specifies as applicable to the stylus system shall be tested.

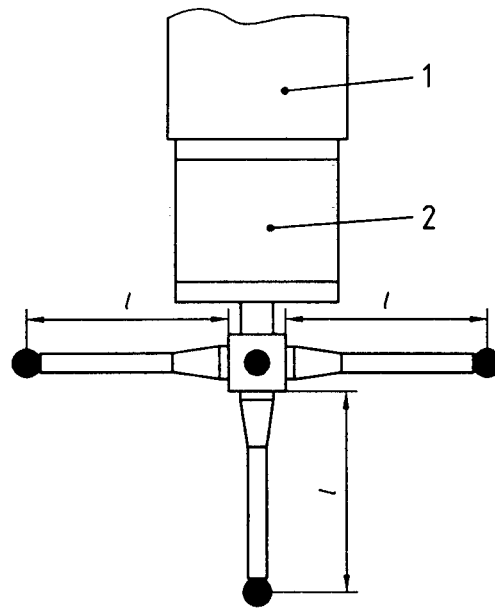
The choice of the location of the test sphere can significantly affect the test results.

5.1.2 Measuring equipment

The material standard of size, the test sphere, shall have a diameter not less than 10 mm and not greater than 30 mm. The test sphere shall be calibrated for size and form. The CMM qualification sphere shall not be used as the test sphere.

5.1.3 Procedure

5.1.3.1 Construct a "star" stylus system composed of one stylus parallel to the axis of the probe and four styli in a plane perpendicular to the axis, each oriented 90° with respect to those adjacent to it. The distance from the probe to the styli connection point shall be the minimum distance possible using the stylus components normally supplied with the CMM (see Figure 1).



Key

- 1 Ram
- 2 Probe

NOTE For clarity, only four of the five styli, and only three shafts, are visible.

Figure 1 — Fixed multiple-stylus probing system of stylus length l

The applicable values of stylus length, l , shall be equal and specified by the CMM manufacturer, and shall be chosen from the following values: 10 mm, 20 mm, 30 mm, 50 mm, 100 mm, 200 mm and 400 mm (see Figure 2). Only those lengths specified by the CMM manufacturer as applicable to the stylus system shall be tested. The stylus components shall be those approved for use with the CMM probing system, unless otherwise specified.

5.1.3.2 Qualify each of the five styli in accordance with the CMM manufacturer's normal operating procedures.

5.1.3.3 The spherical material standard, i.e. the test sphere, should be displaced from the location of the reference sphere used for the probing system qualification in both the X and Y directions a distance at least equal to the largest stylus length used in the tests (see Figure 2). Measure the test sphere using 25 points with each stylus, for a total of 125 points.

The points should be well distributed on the test sphere, covering at least a hemisphere. The recommended point-sampling strategy for a vertical stylus consists of: a point on the test sphere "pole"; four points equally spaced and located 22,5° from the pole; eight points equally spaced, rotated 22,5° from the previous group and located 45° from the pole; four points equally spaced, rotated 22,5° from the previous group and located 67,5° from the pole; eight points equally spaced, rotated 22,5° from the previous group and located 90° from the pole.

For horizontal styli, a similar sampling strategy should be used, with the "pole" defined by the direction of the stylus.

If a stylus- or probe-changing system is supplied with the CMM, five changes shall be performed, each stylus being changed once. However, if fewer than five probe or styli stations are available in the changing system, the maximum number shall be used, with some styli or probes exchanged more than once to achieve a total of five changes.

	MPE_{MF} μm	MPE_{MS} μm	MPE_{ML} μm
Fixed multiple stylus $l = 10 \text{ mm}$			
Fixed multiple stylus $l = 20 \text{ mm}$			
Fixed multiple stylus $l = 30 \text{ mm}$			
Fixed multiple stylus $l = 50 \text{ mm}$			
Fixed multiple stylus $l = 100 \text{ mm}$			
Fixed multiple stylus $l = 200 \text{ mm}$			
Fixed multiple stylus $l = 400 \text{ mm}$			

Figure 2 — Sample fixed multiple-stylus probing system specification sheet

5.1.4 Data analysis

5.1.4.1 Associate a least-squares sphere fit for each group of 25 points taken with a single stylus, for a total of five sphere fits. Calculate the range of the centre coordinates (X, Y, and Z) of all five spheres. The largest of these three ranges yields the location error ML .

5.1.4.2 Associate a least-squares sphere fit on all 125 points taken with all five styli. Record the deviation of the sphere fit diameter from the calibrated value of the material standard of size to give the fixed multiple-stylus probing system size error MS . Similarly, record the range of radii of the 125 points with respect to the least-squares sphere centre, i.e. the sphere form, to give the fixed multiple-stylus probing system size error form error MF .

5.1.5 Repeat the steps given in 5.1.3.1 to 5.1.4.2 for each value of l permitted by the CMM manufacturer.

5.2 Articulating probing systems

5.2.1 Principle

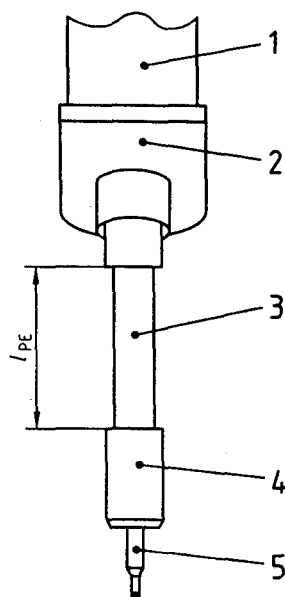
The principle of these tests is to measure the form, size and location of a test sphere using five different angular positions of an articulating probing system (see Figure 3). At each angular position 25 points are measured on the test sphere, for a total of 125 points using all five positions.

If a stylus- or probe-changing system is supplied with the CMM, five changes shall be performed, one before each of the angular positions used. Associate a least-squares sphere fit with each group of 25 points taken at an angular position, for a total of five sphere fits.

The ranges of the centre coordinates (X, Y, and Z) of all five spheres are calculated. The largest of these three ranges yields the location error, AL . In addition, a least-squares sphere fit using all 125 points is examined for the form and size errors of indication. This analysis yields the size error AS and form error AF .

Since the results of these tests are highly dependent on the probe extension length, a series of different extension lengths is considered; only those lengths the CMM manufacturer specifies as applicable to the articulating probing system shall be tested.

The choice of the location of the test sphere can significantly affect the test results.



Key

- 1 Ram
- 2 Articulating probe holder
- 3 Probe extension
- 4 Probe
- 5 Stylus

Figure 3 — Articulating probing system in the vertical position

5.2.2 Measuring equipment

The material standard of size, i.e. the test sphere, shall have a diameter not less than 10 mm and not greater than 30 mm. The test sphere shall be calibrated for size and form. The CMM qualification sphere shall not be used as the test sphere.

5.2.3 Procedure

5.2.3.1 Attach a short (unless otherwise specified, 20 mm), straight stylus and a probe-extension component to the articulating probing system. The probe extension length, l_{PE} , shall be chosen from the following values: 0 mm, 100 mm, 200 mm, and 300 mm (see Figure 4). The stylus and probe-extension components shall be those approved for use with the CMM probing system, unless otherwise specified.

5.2.3.2 Qualify each of the five angular positions of the articulating probing system in accordance with the CMM manufacturer's normal operating procedures. The five angular positions shall consist of one vertical and four horizontal positions, each oriented 90° with respect to those adjacent to it.

5.2.3.3 The test sphere should be displaced from the location of the reference sphere used for the probing system qualification in both the X and Y directions a distance at least equal to the largest extension length used in the test (see Figure 4). Measure the test sphere using 25 points measured in each angular position, for a total of 125 points.

	MPE_{AF} μm	MPE_{AS} μm	MPE_{AL} μm
Articulating probing system Probe extension length $l_{PE} = 0$ mm			
Articulating probing system Probe extension length $l_{PE} = 100$ mm			
Articulating probing system Probe extension length $l_{PE} = 200$ mm			
Articulating probing system Probe extension length $l_{PE} = 300$ mm			

Figure 4 — Sample articulating probing system specification sheet

The points should be well distributed on the test sphere, covering at least a hemisphere. The recommended point sampling strategy for a vertical stylus consists of one point on the test sphere "pole"; four points equally spaced and located $22,5^\circ$ from the pole; eight points equally spaced, rotated $22,5^\circ$ from the previous group and located 45° from the pole; four points equally spaced, rotated $22,5^\circ$ from the previous group and located $67,5^\circ$ from the pole; and eight points equally spaced, rotated $22,5^\circ$ from the previous group and located 90° from the pole.

For styli in horizontal angular positions, a similar sampling strategy should be used with the pole defined by the direction of the stylus.

If a stylus- or probe-changing system is supplied with the CMM, five changes shall be performed with the default styli. For each angular position, the stylus or probe is placed and removed from the changing system to produce a total of five changes during the test.

5.2.4 Data analysis

5.2.4.1 Associate a least-squares sphere fit with each group of 25 points taken at an angular position, for a total of five sphere fits. Calculate the range of the centre coordinates (X, Y, and Z) of all five spheres. The largest of these three ranges yields the articulating probing system location error, AL .

5.2.4.2 Associate a least-squares sphere fit with all 125 points taken with all five angular positions. Record the deviation of the sphere-fit diameter from the calibrated value of the material standard of size to give the articulating probing system size error AS . Similarly, record the range of radii of the 125 points with respect to the least-squares sphere centre, i.e. the sphere form, to give the articulating probing system form error, AF .

5.2.5 Repeat the steps given in 5.2.3.1 to 5.2.4.2 for each probe-extension length permitted by the CMM manufacturer.

6 Compliance with specifications

6.1 Acceptance test

The performance of a CMM with a fixed multiple-stylus probing system is verified according to this part of ISO 10360 when, for each permitted value of stylus length, l , $MF \leq MPE_{MF}$, $MS \leq MPE_{MS}$, and $ML \leq MPE_{ML}$, as specified by the manufacturer and taking into account the uncertainty of measurement according to ISO 14253-1.

The performance of a CMM with an articulating probing system is verified according to this part of ISO 10360 when, for each permitted value of probe extension length, l_{PE} , $AF \leq MPE_{AF}$, $AS \leq MPE_{AS}$, and $AL \leq MPE_{AL}$, as specified by the manufacturer and taking into account the uncertainty of measurement according to ISO 14253-1.

If the performance of a CMM with multiple styli is not verified by the tests, all probing equipment should be thoroughly checked for dust, dirt or any operator-induced faults in stylus-system assembly that could be influencing

the measurement result, including the critical issue of ensuring that all probing system components are in thermal equilibrium. Any faults should be corrected and the test repeated once only, starting from probing-system qualification and using the same target contact points.

6.2 Reverification test

The performance of a CMM with a fixed multiple-stylus probing system is verified according to this part of ISO 10360 when, for each permitted value of stylus length, l , $MF \leq MPE_{MF}$, $MS \leq MPE_{MS}$, and $ML \leq MPE_{ML}$, as specified by the user and taking into account the uncertainty of measurement according to ISO 14253-1.

The performance of a CMM with an articulating probing system is verified according to this part of ISO 10360 when, for each permitted value of probe extension length, l_{PE} , $AF \leq MPE_{AF}$, $AS \leq MPE_{AS}$, and $AL \leq MPE_{AL}$, as specified by the user and taking into account the uncertainty of measurement according to ISO 14253-1.

If the performance of a CMM with multiple styli is not verified by the tests, all probing equipment should be thoroughly checked for dust, dirt or any operator-induced faults in stylus-system assembly that could be influencing the measurement result, including the critical issue of ensuring that all probing system components are in thermal equilibrium. Any faults should be corrected and the test repeated once only, starting from probing-system qualification and using the same target contact points.

7 Applications

7.1 Acceptance test

In a contractual situation between a supplier and a customer such as that described in a purchasing, maintenance, repair, renovation or upgrading contract, the acceptance test described in this part of ISO 10360 may be used to verify the performance of a CMM having a fixed multiple-stylus, or articulating, probing system, in accordance with the specified maximum permissible errors agreed on by the supplier and the customer.

If the supplier does not specify any limitation, the stated maximum permissible errors shall apply for any location and orientation of the test sphere on the CMM.

7.2 Reverification test

The reverification test given in this part of ISO 10360 can be used in an organization's internal quality assurance system for verification of the performance of a CMM used with a fixed multiple-stylus probing system or with an articulating probing system in accordance with the specified appropriate maximum permissible errors as stated by the user with all possible and detailed limitation applied.

7.3 Interim check

In an organization's internal quality assurance system, a reduced reverification test can be used periodically to demonstrate the probability that the CMM conforms with the requirements for maximum permissible errors specified in 6.1.

The extent of the reverification test specified in this part of ISO 10360 may be reduced in respect of the number of styli and the actual measuring points being assessed.

See annex A.

Annex A **(informative)**

Interim check

It is recommended that the probing system be checked regularly between periodic reverifications.

It is recommended that the checking of the probing system be carried out using a set of stylus configurations used during everyday measurement. The interim check should follow the same procedure. Initially, it should be carried out immediately after the reverification test. The stylus configurations, location of reference sphere and other parameters should be noted and subsequently repeated.

Annex B **(informative)**

Relation to the GPS matrix model

For full details about the GPS matrix model see ISO/TR 14638.

B.1 Information about this part of ISO 10360 and its use

This part of ISO 10360 specifies the verification methods for proving conformance of coordinate measuring machines with the specified MPEs. The tests given in this part of ISO 10360 are:

- applicable to a CMM capable of using multiple styli;
- designed to provide information about the ability of a CMM to measure a feature or features using multiple styli, probes, or articulated probe positions;
- performed in addition to the length-measuring tests given in ISO 10360-2, which are conducted using only one stylus.

B.2 Position in the GPS matrix model

This part of ISO 10360 is a general GPS standard which influences chain link 5 of the chains of standards on size, distance, radius, angle, form, orientation, location, run-out and datums in the general GPS matrix, as illustrated in Figure B.1.

Fundamental GPS standards	Global GPS standards					
	General GPS standards					
	Chain link number	1	2	3	4	5
	Size					
	Distance					
	Radius					
	Angle					
	Form of line independent of datum					
	Form of line dependent of datum					
	Form of surface independent of datum					
	Form of surface dependent of datum					
	Orientation					
	Location					
	Circular run-out					
	Total run-out					
	Datums					
	Roughness profile					
	Waviness profile					
	Primary profile					
	Surface imperfections					
	Edges					

Figure B.1

B.3 Related standards

The related standards are those of the chains of standards indicated in Figure B.1.

Bibliography

- [1] ISO 10360-2:—¹⁾, *Coordinate metrology — Part 2: Performance assessment of coordinate measuring machines.*
- [2] ISO 10360-3:2000, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 3: CMMs with the axis of a rotary table as the fourth axis.*
- [3] ISO 10360-4:2000, *Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 4: CMMs used in scanning measuring mode.*
- [4] ISO/TR 14638:1995, *Geometrical Product Specifications (GPS) — Masterplan.*

1) To be published. (Revision of ISO 10360-2:1994)

(Continued from second cover)

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
ISO 10360-1 : 2000 Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 1 : Vocabulary	IS 15635 (Part 1) : 2005 Geometrical Product Specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) : Part 1 Vocabulary	Identical
ISO 14253-1 : 1998 Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1 : Decision rules for proving conformance or non-conformance with specifications	IS 15371 (Part 1) : 2003 Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment : Part 1 Decision rules for proving conformance or non-conformance with specifications	do

The technical committee reviewed the provisions of International Vocabulary of Basic and General Terms in General Metrology (VIM) referred in this adopted standard and decided that it is acceptable for use in conjunction with this standard.

ISO 10360 consists of the following other parts:

- Part 1 Vocabulary
- Part 2 CMMs used for measuring size
- Part 3 CMMs with the axis of a rotary table as the fourth axis
- Part 4 CMMs used in scanning measuring mode
- Part 6 Estimation of errors in computing Gaussian associated features

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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